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THE CLEAR LAKE GNAT

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CONTENTS

	PAGE
Origin of the gnats.....	3
Habits of the gnat.....	4
Description of the gnat.....	6
Life history.....	8
Egg stage.....	8
Larval stage.....	8
Pupal stage.....	9
Overwintering larvae.....	14
Control experiments.....	16
Use of fish.....	17
Attraction to light.....	17
Suction-fan traps.....	18
Electrocuting light traps.....	20
Use of light-trap barriers.....	21
Acknowledgments.....	22

THE CLEAR LAKE GNAT¹

W. B. HERMS²

FOR MANY YEARS there have appeared regularly every summer great swarms of annoying gnats along the shores of Clear Lake, particularly in the vicinity of Lakeport, California. These gnats while being closely related to mosquitoes and for many years included in the same family, are not bloodsucking and probably do not feed at all as adults. The annoyance caused by these insects is due wholly to their extreme abundance and strong attraction to light. The following extract from an unpublished thesis by R. W. Burgess describes this annoyance very well :

The nuisance created by these insects is unbelievable unless actually experienced. At night they sometimes become so numerous around the lights that they hang in a cloud below every exposed lamp. They often become so thick on the screen doors that scarcely any light can penetrate. The insects do not bite or sting but unless one stays in the dark, he will find myriads of these tiny insects buzzing all around him and getting into his eyes, mouth, nose, and even his ears. Besides the gnats there are numerous spiders which feed on the gnats and spin their webs all over the buildings. Soon these webs become laden with dead gnats and festoon everything to which they are attached. From the time the lights are turned on in the evening until about ten or eleven o'clock, the rule is either to keep indoors behind screens, or, if the warm summer evenings are to be enjoyed, to allow no lights.

ORIGIN OF THE GNATS

The writer first gave attention to the gnat problem at Lakeport during the summer of 1916. At that time, as theretofore, most of the people of that vicinity believed that the gnats originated from among the tules in the shallower water of Clear Lake. It is true that then as well as now this shallow tule marsh bred myriads of midges belonging to the family Chironomidae, the larvae of which include the common bottom-living bloodworms. These midges resemble the gnats very closely but differ from them in that the wings are bare, that is, do not possess scales as do the wings of the gnats. No larvae giving rise to gnats were found. Evidence pointed toward an origin farther out in the Lake.

No further field studies were made of the problem except for the determination of the species by Freeborn,³ until the summer of 1927 when through the efforts of the farm-bureau officials of Lake County and Mr. L. C. Barnard, the Farm Advisor, a small fund was raised, making it possible to station a field investigator at Lakeport, under the direction of the writer. Much of the information which we now possess concerning the biology of these gnats was secured during that summer by Mr.

¹ Received for publication March 18, 1937.

² Professor of Parasitology and Entomologist in the Experiment Station.

³ Freeborn, Stanley B. A new chaoborid gnat, *Chaoborus lacustris* sp. nov. (Chaoboridae: Diptera). Pan-Pac. Ent. 2(4):161-65. 1926.

Robert W. Burgess, who camped on the shores of Clear Lake near Lakeport from the fifteenth of May to mid-September of 1927. Again a careful search for gnat larvae was made in the tule beds and again without effect. That the gnat larvae actually lived in Clear Lake was evidenced by the fact that numerous castoff pupal skins were continually being washed ashore. These were believed to be the pupal skins of this very species because of their great abundance. Burgess started his search among the tules at the shore lines and gradually worked out toward deeper water. Burgess describes his quest as follows :

But it was not until the deeper water some distance from shore was reached that a single small, transparent larva was finally taken in an improvised dragnet. This net consisted of a cone of fine copper screen about one foot deep and a little less than a foot in diameter at the mouth. Over the apical end was tied a small tobacco sack. Three cords, fastened around the mouth, attached the net to a line by which it was dragged through the water.

In spite of hours of patient dragging, nothing more was found for several days, and it was not until one afternoon just before dusk that several hundred were taken. Before very long several thousand larvae and many pupae had been captured. The emergence of adults of *Chaoborus lacustris* from these pupae ended the search.

During the next few years no extended work was done on this project, although the writer and various members of his staff made numerous trips to Clear Lake to observe the behavior of the gnats under various conditions. Much new information was gained during the summers of 1933, 1934, and 1935, when Mr. J. K. Ellsworth was stationed at Lakeport. In order to obtain information concerning the overwintering stage of the gnat two investigators, Mr. H. V. M. Hall and Mr. M. R. Bell, were detailed under the S.E.R.A. during the winter season of 1935-36. These later investigations proved that the larvae actually do not inhabit the shallow waters close to shore, for they were never taken within 200 feet of the shore line and were not plentiful nearer than 400 or 500 feet. However, from this point and well out into the Lake, they were to be found in large numbers. The work was done about $1\frac{1}{2}$ miles north of Lakeport, where the water, a couple of miles offshore, was not over 15 or 20 feet deep. The results of later seining for larvae are given in another section.

HABITS OF THE GNAT

The gnats usually make their appearance early in May and are present to a greater or lesser degree until about mid-October. Swarms are likely to appear after two or three consecutive days of warm quiet weather. The gnats show a strong aversion to wind. Even on warm breezy days the gnats do not become active until the wind dies down toward evening. However, the insects may be carried great distances by the wind and

have been reported by local deer hunters (men who are usually observant and thoroughly familiar with the insect) in great numbers in the manzanita bushes on the foothills 8 to 10 miles from the Lake. Ranchers several miles from the lake shore report occasional invasions at times when the wind has been unusually strong in their direction for several days. The gnats have now been reported as occurring at Lake Pillsbury and Blue Lakes, being carried there mechanically on boats, automobiles, or by the wind.

Burgess made this very interesting observation on the afternoon of June 4, 1927 :

About two hours before sundown on the day in question, the writer was working among some willows and tules in the shallow water near the shore just as the breeze died down. The stillness was suddenly broken by a noise almost shrill in its intensity, which sounded like a swarm of bees only of a much higher pitch. Closer investigation showed the air to be filled with millions of flying gnats which seemed to be springing up from everywhere, along the shore and off the lake. Thinking that they had recently emerged and were very likely still emerging, I jumped into my canoe and hurriedly paddled out on the Lake. However, nothing was seen except hordes of the insects flying over the water so that it appeared as if a mist had suddenly sprung up out of the lake. It was noticed that although there were as many gnats over the water as there were in the bushes along the shore, the high-pitched hum was not so noticeable. This difference was later explained after mating had been observed.

Mating took place, especially on warm days, about five or six o'clock in the afternoon or as soon as the sun began to set and the wind died down. On days when the wind blew more or less throughout the evening, the activity was slight and but few insects were noticed. The favorite location was well off the ground in some leafy tree or clump of bushes. A most popular rendezvous was in an apple tree just outside the tent, about 500 feet from the lake. This tree was about 20 feet high and the head was nearly 25 feet in diameter. Mating used to start on the shady or eastern side but, as the sun sank lower, the insects shifted to the sunnier, western side.

The characteristic high-pitched hum of the courting males seemed to burst suddenly upon the air as if at a given signal. The males were continuously flying around the tree and into it to mate with the females which were resting on the outer leaves. The careful use of a small, fine sweep net showed that two-thirds of the insects resting on the leaves were females while those flying around the tree were nearly all males. The process of mating is very simple and to accomplish this the male flies into the tree to the waiting female.

No dissections were made of these gnats either just before or just after mating ; but, judging from observations taken during the time the process was going on, it seems as if one male is capable of fertilizing more than a single female, and that the same female may copulate with several males, at least more than one. There was no apparent regular migration of either males or females to and from the tree, but the numbers seem to increase steadily until shortly before sundown, when the females began to leave for the lake, probably to oviposit.

The gnats begin emerging from pupae early in the afternoon and continue to emerge throughout the night. They fly shoreward immediately and usually remain there until the next evening. During the day, to

mid-afternoon, especially on hot days, the gnats may be found resting on the trees, tules, grass, and the leeward side of buildings.

In the early afternoon there is a characteristic easterly wind which blows across the Lake. The newly emerged gnats come shoreward with this wind and intermingle with the gnats from the previous day. Almost as if by magic a westerly wind comes up between 3 and 4 o'clock and dies down gradually by sunset when the Lake is usually calm.

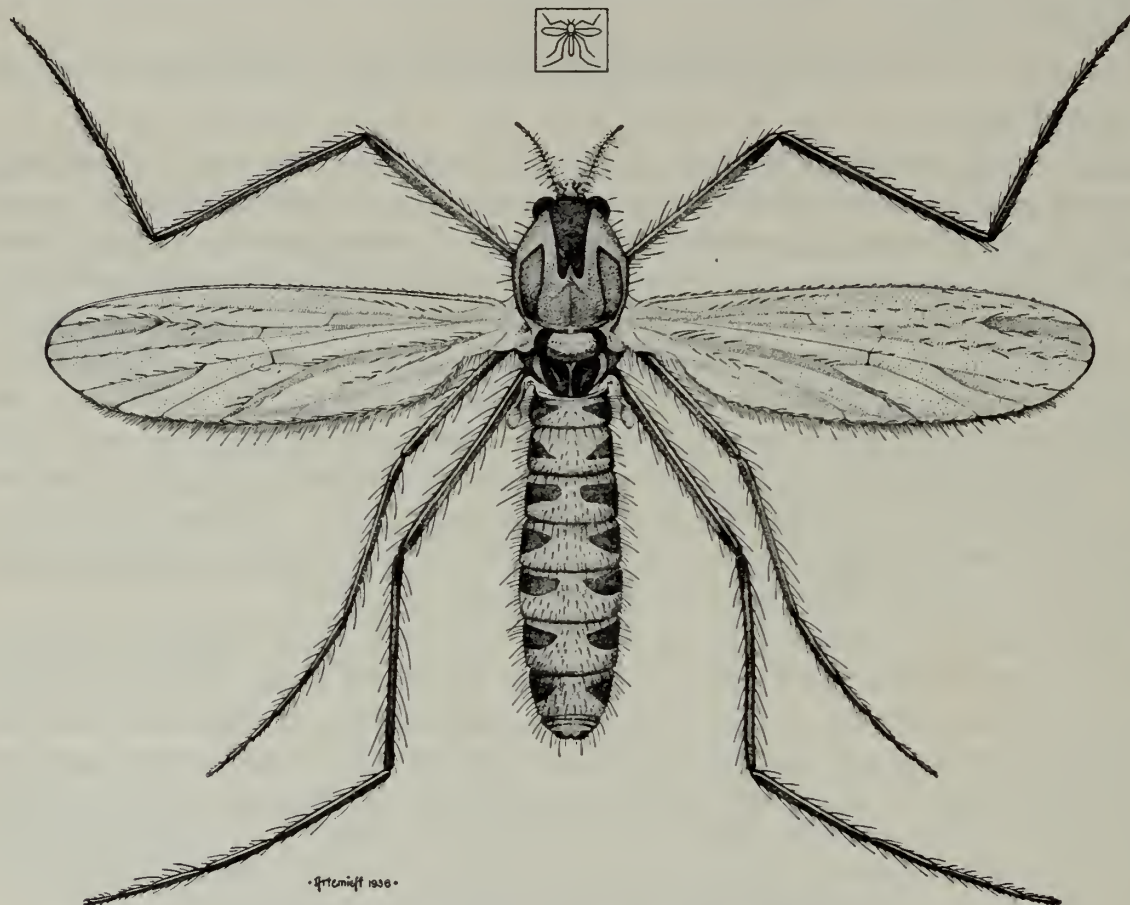


Fig. 1.—Female Clear Lake gnat. The insert shows the insect natural size.

Just about sundown when the wind has died down, the characteristic hum of the courting males begins and mating takes place as already described. After sunset an examination of gnats collected along the shore line showed 75 per cent females up to about 10 o'clock, when the males began to predominate.

The lakeward migration of the females starts almost exactly 15 minutes before sundown. It is doubtful whether the females of *Chaoborus lacustris* continue to oviposit throughout the entire night, since most adult activity ceases with the chilling effect of the late evening breeze. The great activity during the evening leads us to believe that oviposition takes place early.

DESCRIPTION OF THE GNAT

This gnat was described as a new species by S. B. Freeborn of the University of California in 1926 and was named *Chaoborus lacustris*, being

placed in the family Chaoboridae (order Diptera), to separate the species from the mosquitoes (family Culicidae). The subfamily Corethrinae earlier included this group of insects, but this subfamily was later changed to Chaoborinae, before it was separated completely from the family Culicidae.

In color these gnats (figs. 1 and 2) are brown with a vestiture of straw-colored hairs. They range from 4 to 5 millimeters in length. The

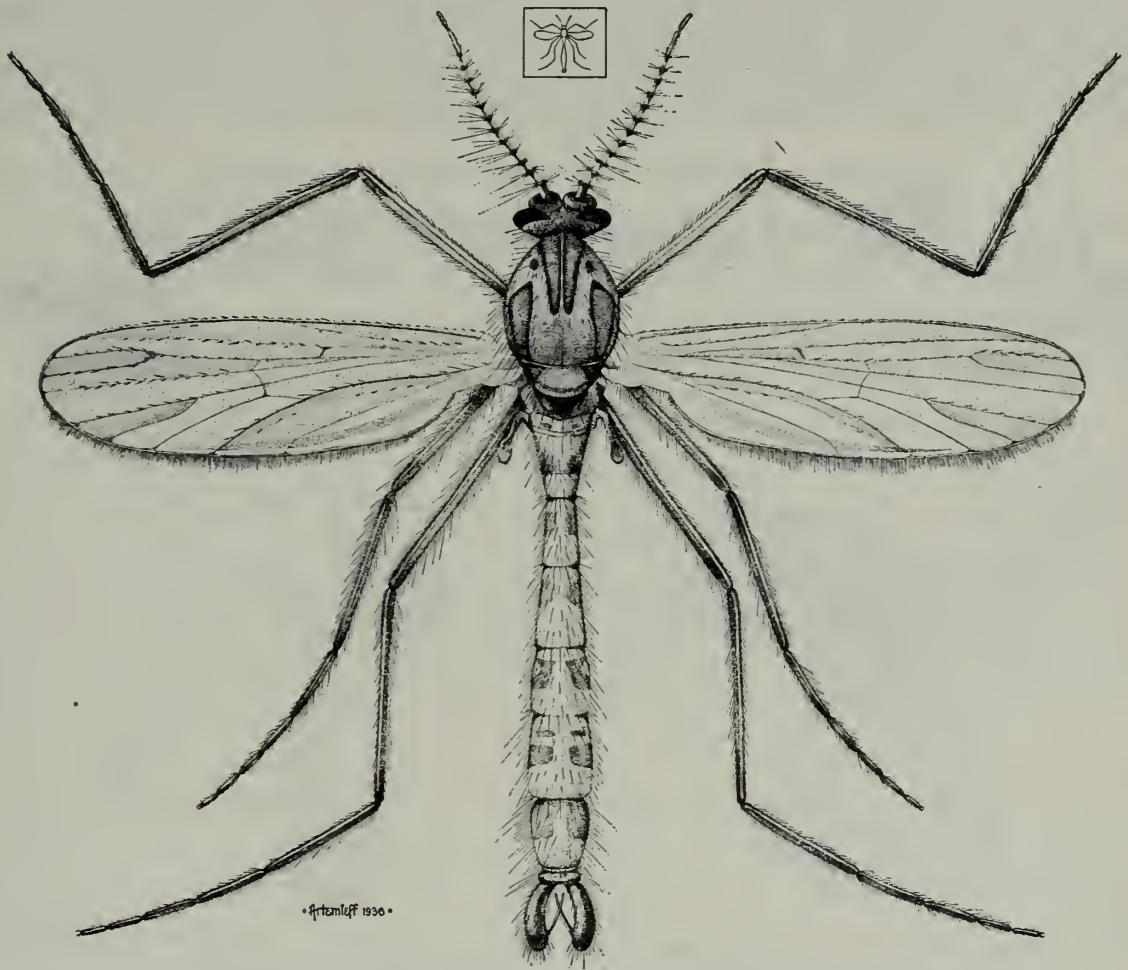


Fig. 2.—Male Clear Lake gnat. The insert shows the insect natural size.

antennae are plumose. The wing veins are clothed with narrow, hairlike scales; the anterior margin of the wing is dotted with narrow, appressed scales, while the posterior margin has two lengths of lanceolate scales, one short and the other longer than the greatest distance between the anal vein and the hind margin. The males may be recognized by the presence of claspers at the tip of the abdomen (fig. 2). This species falls near *Chaoborus punctipennis* Say and *C. astictopus* D. and S. It differs from both in having very pronounced markings on the mesonotum and in the form of the paraprocts. The abdominal markings in the female agree closely with those of *astictopus* and the chaetotaxy of the gono-

style is very similar to that of *punctipennis*. For a complete technical description of the species the reader is referred to the citation in footnote 3.

LIFE HISTORY

Egg Stage.—Eggs are freely deposited by the female gnats in captivity. The numerous minute dark lead-colored, cigar-shaped eggs (fig. 3, *B*) are deposited on the surface of the water where they form geometrical designs as do the eggs of anopheline mosquitoes. Unlike the eggs of most mosquitoes the gnat eggs sink to the bottom when the water is slightly agitated. Under laboratory conditions the eggs hatched within 12 hours. Under natural conditions in cooler water the incubation period would

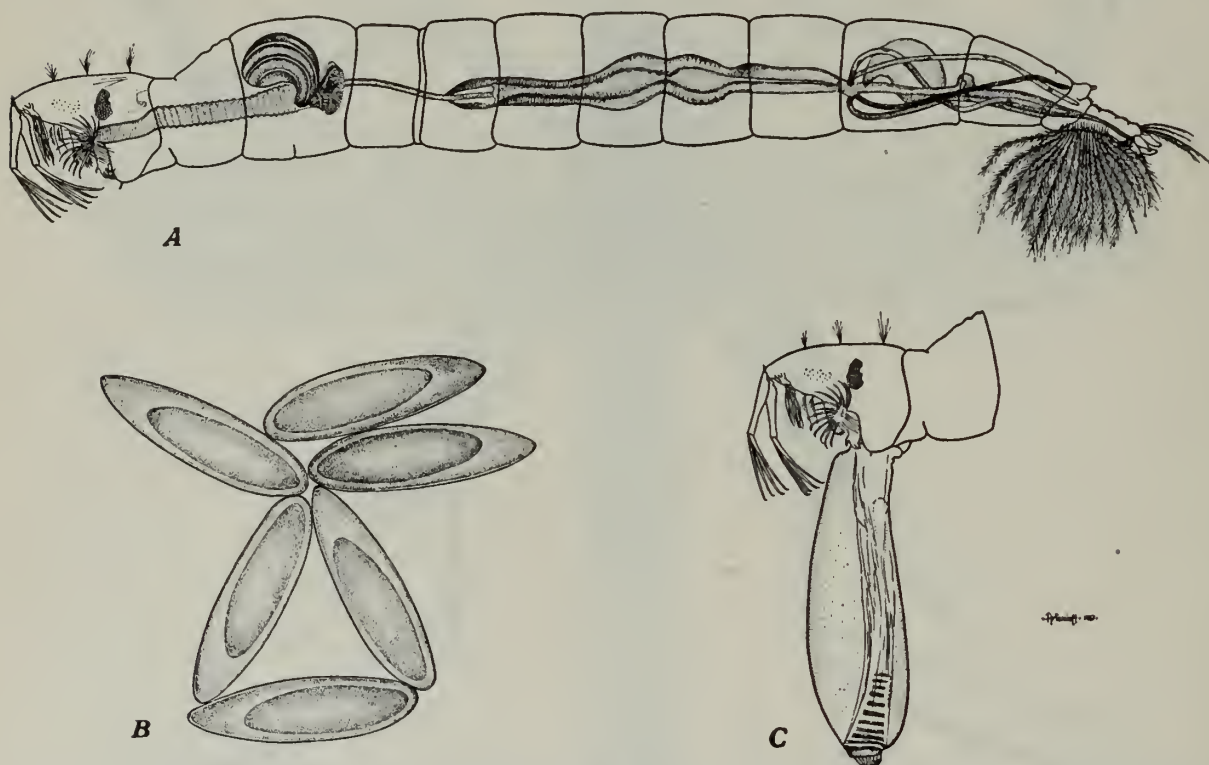


Fig. 3.—Eggs and larva of the Clear Lake gnat: *A*, larva; *B*, eggs; *C*, the everted pharyngeal basket of the larva. All greatly enlarged.

no doubt be longer. From observations made in the field laboratory, it is assumed that the female gnats returning to the Lake after fertilization deposit their eggs on the surface of the water where the eggs remain but briefly and then sink to the bottom where they hatch.

Larval Stage.—The decidedly elongate larvae (fig. 3, *A*) are almost transparent and are seen only with difficulty, except when moving, even in fairly clear water—hence the name “phantom larvae.” When fully grown they are from 8 to 10 mm in length. These larvae differ materially from mosquito larvae in that they need not come to the surface of the water for air. Respiration is probably accomplished by means of gills (four in number) surrounding the anus. Although the larvae grow rap-

idly, the length of time required for the completion of this stage is not definitely known for this species. Burgess believed this stage required probably only about four or five weeks during the summer, and that there might thus be overlapping generations. That this is the overwintering stage was later determined when Mr. J. K. Ellsworth collected full-grown larvae on February 1, 1934, at a depth of 32 feet. These were found in the bottom mud near the channel well over toward Lucerne. The bottom temperature for that date was 49° F at a depth of from 15 to 32 feet; and the temperature of the air at 2 p.m. was 58°. Earlier in the paper it was pointed out that Burgess, who worked during the summer, found the larvae in large numbers at a depth of from 15 to 20 feet at a distance of about 1½ miles north of Lakeport. They were not found in shallow water and were never taken within 200 feet from shore.

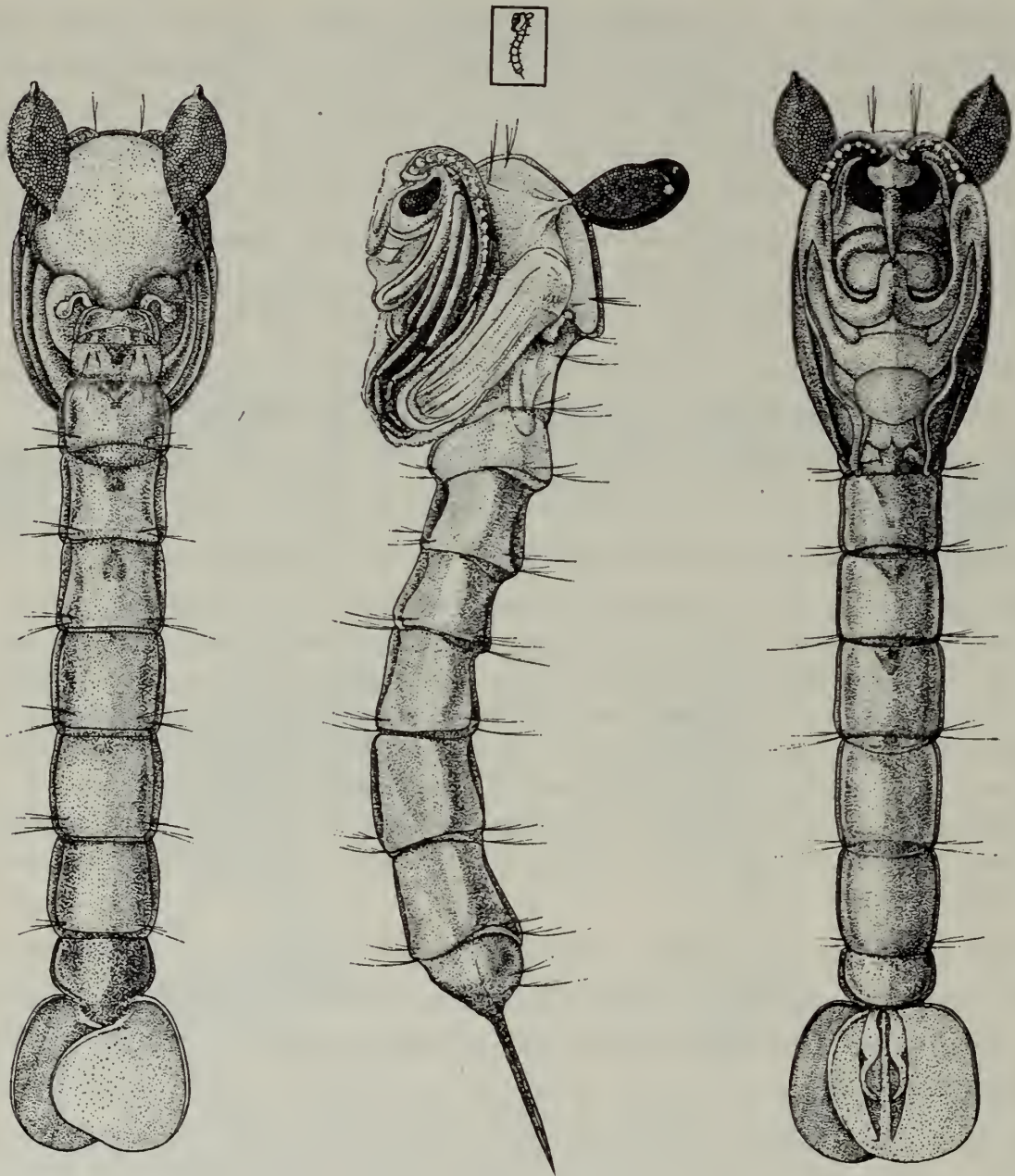
The larval food consists of minute plant life such as algae and small aquatic animals such as crustaceans, and in captivity they will readily eat each other. Burgess, who has observed their feeding habits, states:

Although they have been observed to lower or raise themselves slightly in order to maneuver into a better position, they usually remain motionless and wait until their prey approaches within about an inch, when they double up like an S and quickly lash out, grabbing their prey with their ferocious-looking mouth parts and cephalic appendages. The larvae possess a peculiar pharyngeal basket (fig. 3, C) which functions as a combination crop and "strainer" to macerate the food and to strain out the indigestible parts. This organ is capable of being everted so that all indigestible chitin and similar materials can be washed away and the whole apparatus returned to its normal position.

During the daytime most of the larvae are buried in the soft mud at the bottom of the lake, but seem to manifest a kind of nocturnal periodicity, coming out of the ooze late in the afternoon and evening, probably in search of food.

Pupal Stage.—When the larvae are fully grown after overwintering and the temperature and other conditions, not as yet known, are favorable, pupation takes place. This transformation is accomplished with great rapidity. During winter and spring dredging operations of 1934–35 the first pupa was found March 23. During April of that year the number of pupae increased rapidly. Sample dredgings during April showed 234 larvae and 7 pupae on April 19; 244 larvae and 6 pupae on April 20; 146 larvae and 10 pupae April 22; and 100 larvae and 8 pupae on April 24. Pupation apparently takes place in the bottom ooze where both larvae and pupae are readily taken in samples of this ooze and mud throughout the summer, though in differing proportions. Burgess states that larvae were far more plentiful than pupae by the middle of November, just the reverse of conditions in August.

In order to permit the safe emergence of the gnats, the pupae rise to the surface. The pupae (fig. 4) are free-swimming, not unlike those of mosquitoes. They measure from 4 to 5 mm in length. In the field labora-



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Fig. 4.—Various views of the pupa of the Clear Lake gnat. The insert shows the pupa natural size.

tory the pupal stage has lasted as long as two weeks, although there were some emergences in a much shorter time. Temperature is no doubt an important factor in this stage of development. When pupation is completed, the gnats literally “pop” out of their pupal skins, balance momentarily on the water, and quickly fly away shoreward.

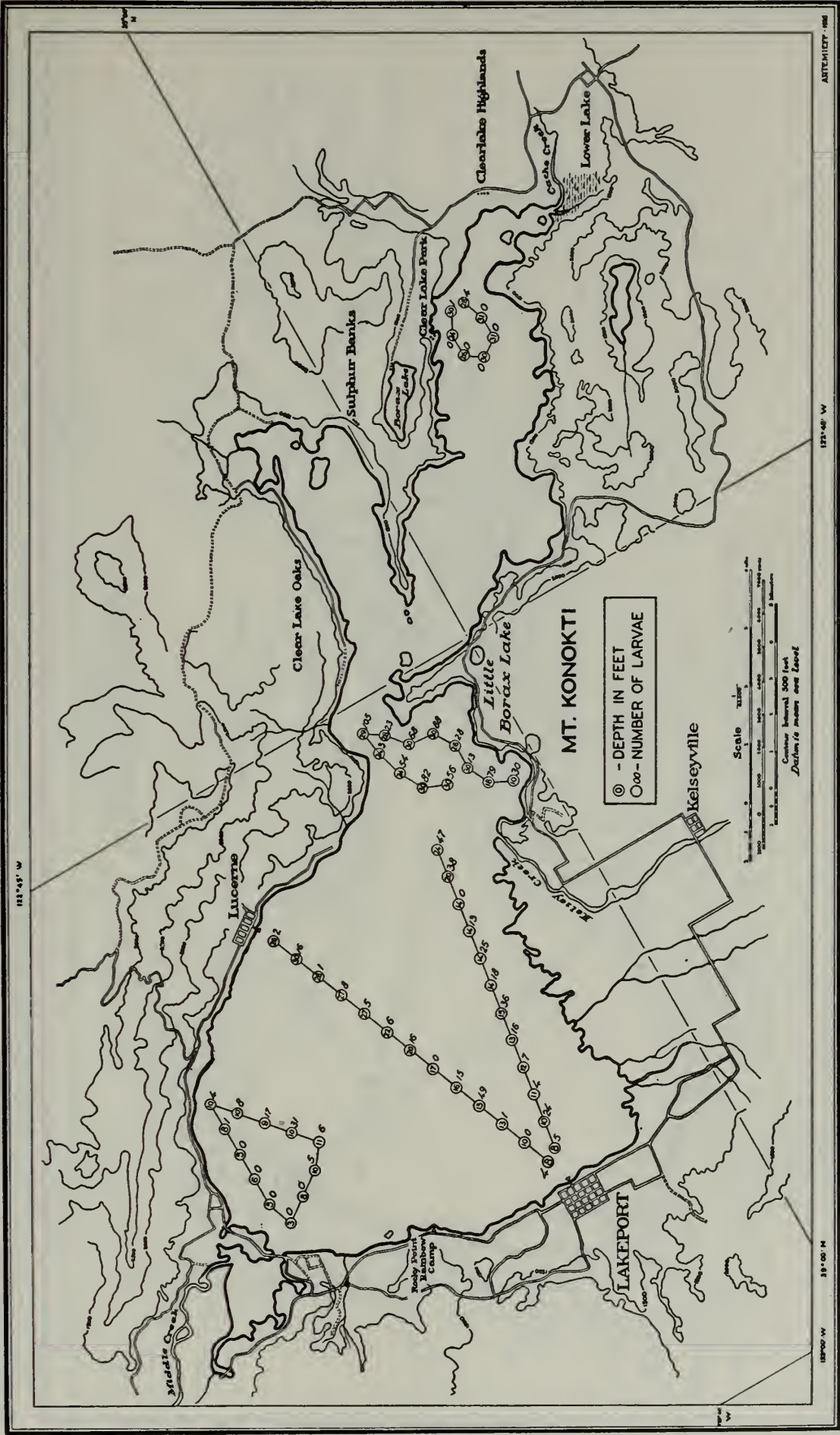


Fig. 5.—Map of Clear Lake showing numbers of larvae taken during December, 1934, by dredging at various locations and depths. (See table 1.)

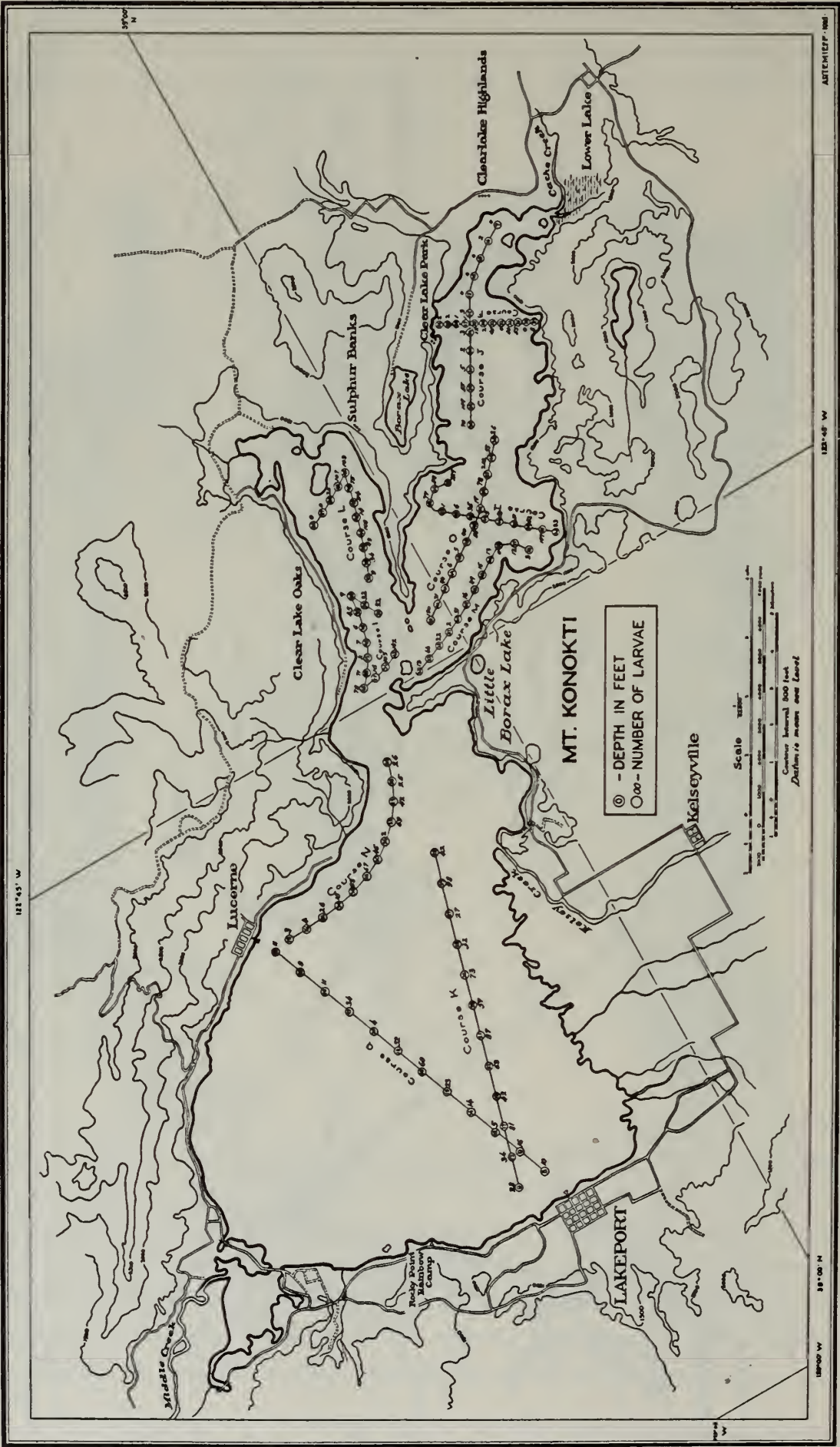


Fig. 6.—Map of Clear Lake showing numbers of larvae taken during January, 1935, by dredging at various locations and depths. (See table 2.)

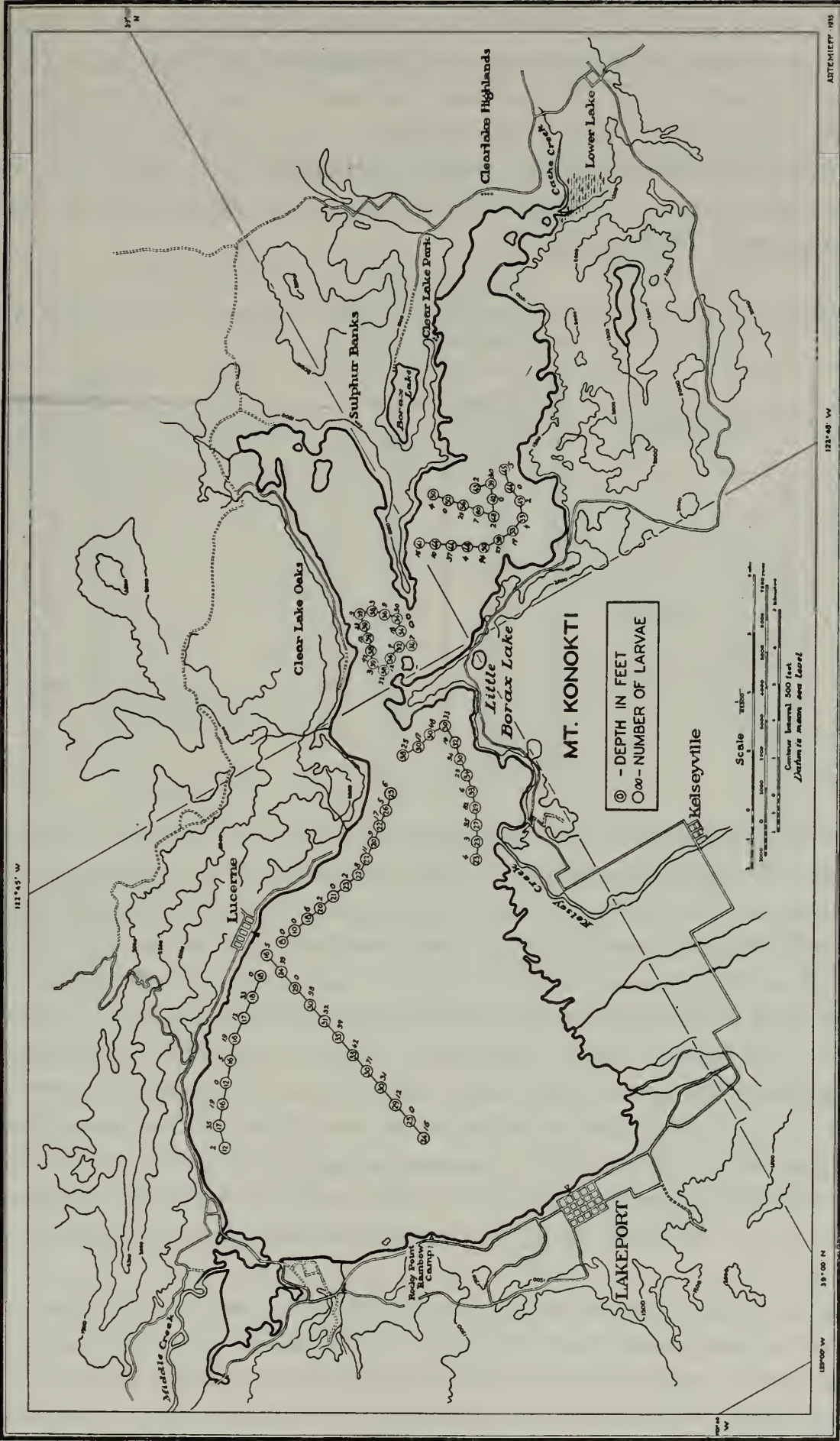


Fig. 7.—Map of Clear Lake showing numbers of larvae taken during February, 1935, by dredging at various locations and depths. (See table 3.)

OVERWINTERING LARVAE

To determine the development of larvae and their distribution during the winter season, a winter camp was established at Clear Lake, California, where Mr. H. V. M. Hall was stationed continuously during the months of December (1934) and January to April (1935) inclusive. A local improvement association placed a cottage at Clear Lake Park, together with certain equipment such as boats, at the disposal of Mr. Hall for purposes of the investigation.

TABLE 1
NUMBER OF LARVAE TAKEN BY DREDGING AT VARIOUS LOCATIONS AND DEPTHS IN
DECEMBER, 1934

Depth of water in feet	Number of larvae taken with each haul	Average number of larvae per haul	Depth of water in feet	Number of larvae taken with each haul	Average number of larvae per haul
3	0.....	0.0	17	0.....	0.0
5	0, 0.....	0.0	18	79.....	79.0
6	0.....	0.0	20	16, 38.....	27.0
8	1, 0, 4, 5.....	2.5	22	6.....	6.0
9	17.....	17.0	24	47, 0, 3, 54.....	26.0
10	8, 4, 5, 31, 0, 24, 30.....	14.6	26	2, 0, 28.....	10.0
11	6, 4.....	5.0	27	5, 8.....	6.5
12	7.....	7.0	28	1, 4, 23.....	9.3
13	1, 49, 16.....	22.0	29	105.....	105.0
14	18, 25, 13, 0.....	14.0	30	16, 1, 0, 13, 88, 68, 82, 56....	40.5
15	36.....	36.0	31	0, 0.....	0.0
16	15.....	15.0			

Courses were selected for dredging as shown on the maps in figures 5, 6, and 7. In dredging operations, efforts were made to standardize the procedure so that the results would be comparable. Small dragnets were used consisting of bags 18 inches deep attached to metal triangles of 1-foot sides. After measuring the depth at the location of each haul, the dredge was pulled approximately 100 feet with the dredge line at an angle of 45 degrees with the surface of the water. The netting was changed as often as rents developed, and the net was washed by reversing it in the wash of the boat after every haul. The results of each haul were put in individual gallon cans and a larval count of each can was made upon return to the laboratory. The results of dredging at various depths at the different locations during December are summarized in table 1.

Figure 5 shows the locations from which the hauls were made. The number in each circle shows the depth of the lake in feet, and the number near the circle shows the total number of larvae taken in that haul at that depth. Five courses in various parts of the Lake were completed in 1934.

During the month of January (1935) dredging operations were continued over courses shown in figure 6. The same dredging equipment and methods were used as described for December. The results are shown in table 2.

TABLE 2
NUMBER OF LARVAE TAKEN BY DREDGING AT VARIOUS LOCATIONS AND DEPTHS IN
JANUARY, 1935

Depth of water in feet	Number of larvae taken with each haul	Average number of larvae per haul	Depth of water in feet	Number of larvae taken with each haul	Average number of larvae per haul
7	0.....	0.0	30	25, 2, 32, 2, 5, 18, 45, 26.....	19.4
8	10.....	10.0	31	44, 33.....	38.5
9	16, 28.....	22.0	32	72, 45, 0, 55, 9.....	34.2
12	5.....	5.0	33	11, 8, 1, 98, 69.....	37.4
14	14.....	14.0	34	32, 105, 109.....	82.0
15	23, 2, 3, 34.....	15.5	35	9.....	9.0
16	60, 2, 0.....	20.6	36	55, 70, 26, 98.....	62.2
17	0, 81.....	40.5	38	45, 6, 71, 43, 34, 0, 26.....	32.1
18	52, 77, 0, 3, 3, 4.....	23.1	40	109, 51, 44.....	68.0
19	42.....	42.0	42	142, 107, 14, 49, 15, 67, 31....	60.7
20	4, 2.....	3.0	44	40, 51, 197, 6.....	73.5
21	87.....	87.0	45	7, 78, 13, 180, 5.....	56.6
22	63, 13, 44.....	40.0	46	55.....	55.0
23	34, 59.....	46.5	47	54.....	54.0
24	88, 3, 73, 26, 2.....	38.4	48	42, 35, 103, 75, 68, 58.....	63.5
25	22, 42, 25.....	29.6	49	6.....	6.0
26	2, 11, 0.....	4.3	52	17.....	17.0
27	1, 16, 27, 0, 2, 12.....	9.6	54	78.....	78.0
28	2, 9, 32, 42.....	21.2	58	202.....	202.0
29	1, 11, 229, 16.....	64.2			

Referring to the results for January as shown in table 2, Mr. Hall reports that there was no change in the size of the larvae as compared with December, and no pupae were taken. The results of February dredging are shown in table 3; the dredging courses appear in figure 7.

To determine the distribution of the larvae with reference to the lake bottom, dragnets were attached to the drag line in series for sampling at various depths simultaneously, and towed for a total distance of nearly a mile. The results are summarized in table 4.

Some information was gained as to the distribution of the larvae at various times of the day by making net drags, although these were not made on the same day. The results are shown in table 5.

The data presented in table 5 are not sufficiently large for positive deductions but together with the data shown in tables 1 and 2, there is evidence to support the opinion that the larvae when present in deeper water swim mostly in the first 5 feet above the bottom, influenced perhaps by the time of day; for example, the results of the few dredgings indicate a larger number at high levels during the hour between 9 and

10 a.m. The small numbers taken at the one-foot-from-bottom level are not significant because the net fills quickly with mud when dragged at the one-foot level and counts are difficult to make.

CONTROL EXPERIMENTS

The successful and economical control of an insect depends largely upon a knowledge of its life history and habits. Control of the Clear Lake gnat in the egg stage does not appear to be feasible because the

TABLE 3
NUMBER OF LARVAE TAKEN BY DREDGING AT VARIOUS LOCATIONS AND DEPTHS IN
FEBRUARY, 1935

Depth of water in feet	Number of larvae taken with each haul	Average number of larvae per haul	Depth of water in feet	Number of larvae taken with each haul	Average number of larvae per haul
10	0.....	0.0	32	14, 12.....	13.0
12	2, 0.....	2.0	33	6, 71.....	38.5
16	5, 19, 5, 19.....	12.0	34	26, 18, 30.....	24.7
17	35, 12.....	23.5	35	42.....	42.0
18	6, 33, 0.....	13.0	36	9, 23.....	16.0
20	2, 9.....	5.5	38	25, 23, 12, 3, 9.....	14.5
21	0.....	0.0	39	27, 30, 3, 23, 42.....	25.0
22	8, 11, 5.....	8.0	42	0.....	0.0
23	4, 3, 2, 11.....	5.0	44	0, 10, 18.....	9.3
24	39, 3.....	21.0	45	5, 2, 2.....	3.0
25	16, 6.....	11.0	47	16.....	16.0
26	5.....	5.0	48	4, 37.....	20.5
27	95.....	95.0	50	19, 94, 0, 4.....	29.2
29	82, 98, 0.....	60.0	53	4.....	4.0
30	94, 33, 48, 7, 32, 31, 12.....	36.7	56	29.....	29.0
31	39.....	39.0	60	7.....	7.0

TABLE 4
DISTRIBUTION OF LARVAE AT VARIOUS LEVELS

Elevations above bottom in feet	Number of larvae taken with each haul	Total number of larvae	Average number of larvae per haul	Elevations above bottom in feet	Number of larvae taken with each haul	Total number of larvae	Average number of larvae per haul
1	20, 2, 0, 0, 0, 2, 0, 11, 0, 0, 0, 0, 1.....	36	2.8	10	0, 0, 0, 0, 0, 1.....	1	0.1
2	0, 2, 0, 0, 1, 0, 11...	14	2.0	12	0, 2.....	2	1.0
3	2, 8, 0, 1, 1, 0, 0....	12	1.7	15	0, 0, 0, 0, 1, 1.....	2	0.3
5	1, 0, 1, 0, 0, 7.....	9	1.5	20	0.....	0	0.0

eggs are deposited upon the water singly and quickly sink to the bottom. Since the larvae do not come to the surface to breathe as do mosquito larvae, the use of oil or a similar larvicide applied to the surface of the water does not apply even though other conditions permitted. Wind would break the oil film, there would be danger to fish and fish food, and the oil would be a nuisance to the proper use of the lake resorts.

Use of Fish.—Tests were made by the Farm Advisor, using top minnows (*Gambusia*) as a possible control; but because the gnat larvae in all stages occur far removed from the shore and in deep water, the top minnows, which remain close to shore and in shallow water, proved useless.

Some consideration has been given to the use of the gnat larvae as natural food by fish already present in Clear Lake. Undoubtedly fish feed upon larvae in large numbers; as many as 100 of these were found in the stomach of a fish known locally as a “calico bass.” A species of fish

TABLE 5
RESULTS OF DREDGING INDICATING VERTICAL DISTRIBUTION OF LARVAE AT DIFFERENT TIMES OF THE DAY

Time of day and weather conditions	Elevations above bottom in feet	Number of larvae taken in each haul	Average number of larvae per haul
8 to 9 a.m. (Weather calm, high fog, and drizzle)	1	0, 0, 8, 0, 1.....	1.8
	3	2, 8, 2, 0, 1.....	2.6
	6	0, 0, 0, 1, 2.....	0.6
	10	0, 0, 0, 0, 0.....	0.0
	15	0, 0, 0, 0, 0.....	0.0
9 to 10 a.m. (Weather bright, clear, breeze with whitecaps on water)	1	2, 1, 0, 2.....	1.2
	3	1, 13, 3, 7.....	6.0
	6	22, 2, 2, 5.....	7.7
	10	3, 1, 1, 0.....	1.2
	15	3, 0, 0, 0.....	0.7
1 to 2 p.m. (Weather clearing after 4 days of rain and wind)	1	2, 0.....	1.0
	3	5, 1.....	3.0
	6	0, 2.....	1.0
	10	0, 0.....	0.0
	15	0, 0.....	0.0

which feeds in or near the bottom ooze where the larvae occur, principally during the winter months, might prove of some value, although difficulties might be encountered in the introduction of a new species of fish.

Attraction to Light.—The tremendous attraction that light has for the gnats is a matter of common observation. It was early believed that this powerful influence might be used in combating these insects. Our investigations have shown that the Clear Lake gnat on emergence from the water flies to the shore where mating takes place, after which the females travel to the lake for purposes of oviposition. This striking habit of the insect offers an unusual opportunity to destroy the females by trapping before the eggs are laid.

Many methods of killing the gnats have been tested, such as the use of heat, open fire, suction-fan traps, and electrocution. An earlier method consisted of a pot of burning oil over which was hung a 300-watt lamp.

The necessity of refilling the pots and lighting them daily as well as the unpleasantness of the smoke and dead insects soon eliminated this method.

Suction-Fan Traps.—During the summer of 1927 several existing types of light traps were tested, all of which attracted gnats, but none of which disposed of the insects effectively. The electrocuting devices

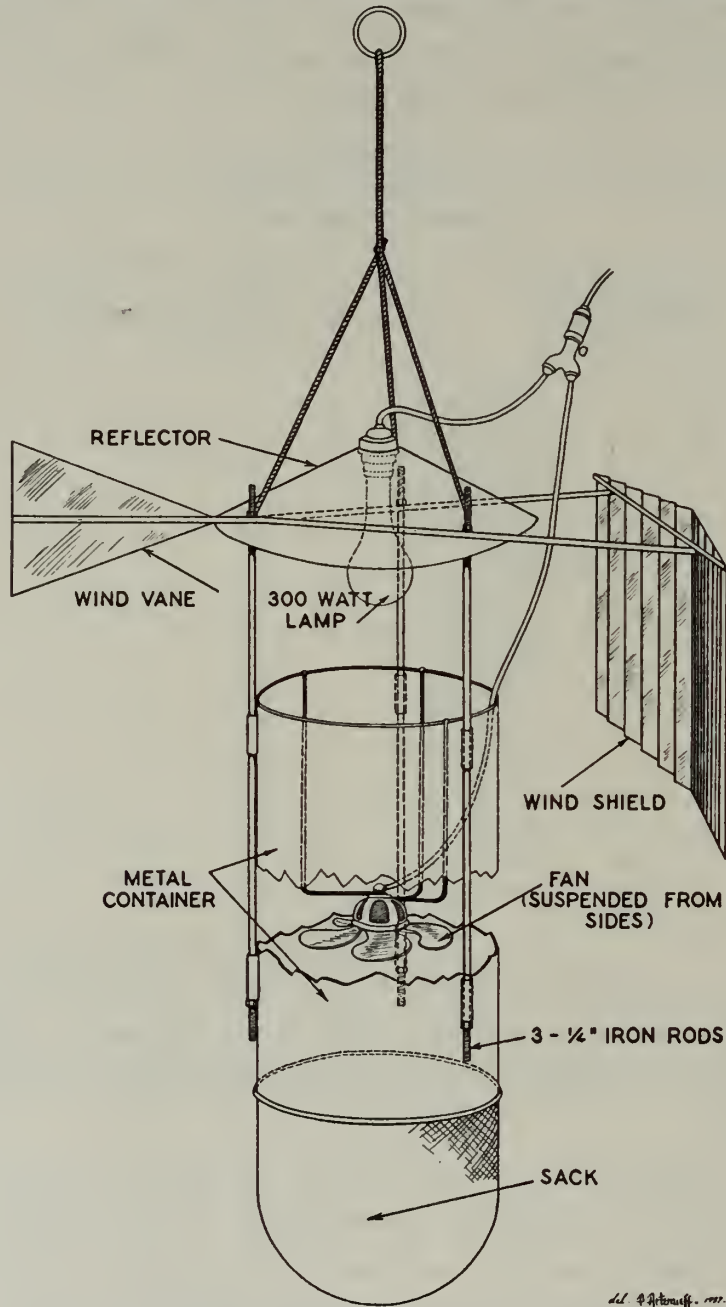


Fig. 8.—Diagrammatic drawing of combined light and suction-fan trap showing arrangement of principal parts.

tested soon became clogged; also the gnats caught fire and generally after brief operation the traps became ineffective until cleaned. The idea of combining an electric light and a suction fan to obviate clogging was then conceived and a trap was devised by Burgess which gave encouraging results. This trap (fig. 8) was first described elsewhere. The

original trap,⁴ later somewhat modified for commercial purposes, consisted of the following parts: (1) an inverted funnel-shaped tin reflector, 18 inches in diameter, provided with a light socket; (2) a 300-watt lamp to attract the gnats; (3) a tin sleeve about a foot in diameter, suspended from the reflector at a distance of about 10 inches by means of three $\frac{1}{4}$ -inch rods, allowing clearance for the gnats to come to the light;

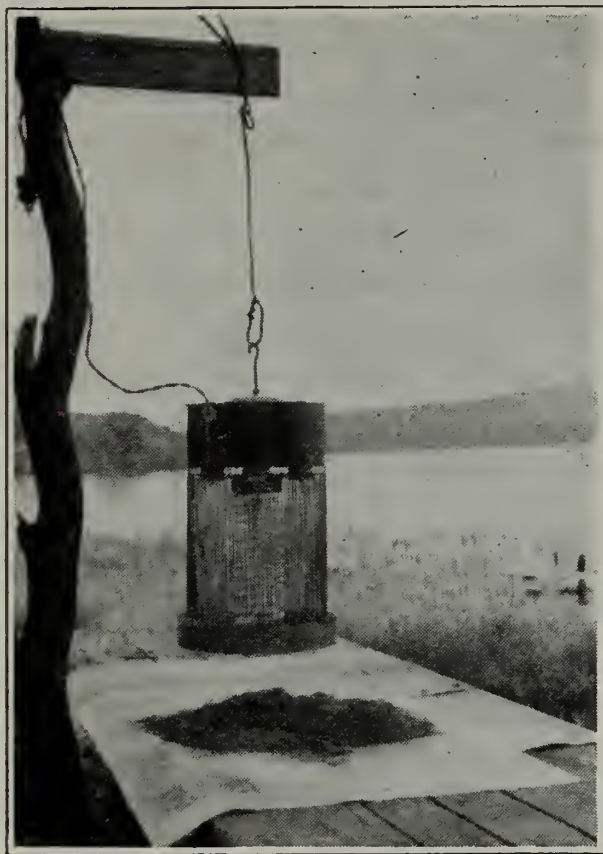


Fig. 9.—One of the earlier types of electrocuting insect traps. The general character of the shore line of Clear Lake is shown in the background.

(4) a small fan, with motor, the latter attached to the sleeve, and designed to suck the insects down from the light by the action of the fan; (5) a black muslin bag about 3 feet long drawn over the lower end of the sleeve; (6) a windshield made of strips of "Cello-glass" arranged shutterlike on a wooden frame lengthwise of the trap. The windshield is necessary because the slightest breeze will push the cloud of gnats away from the trap and consequently away from the influence of the suction fan. Opposite the windshield and attached to the same wooden frame was placed a wind vane, also of Cello-glass.

When the trap was in use it was suspended from a pulley attached to an arm on a pole planted at the water's edge. Best results were achieved when the trap was 8 or 9 feet from the ground. With this crude device 2

⁴ Herms, W. B., and R. W. Burgess. Combined light and suction fan trap for insects. *Electrical West* 60(14):204-6. 1928.

pounds of gnats were trapped in 2 hours, a total of 156 pounds during one summer. Among the difficulties in operating this trap were: (1) clogging with insects, particularly on still warm evenings when the gnats were unusually numerous; (2) since many of the gnats in the bag remained alive, their disposal, as well as the operation of the trap, required almost constant attention.

Electrocuting Light Traps.—During the summers of 1933, 1934, and 1935 Mr. J. K. Ellsworth was stationed at intervals near Lakeport for the purpose of investigating the use of electrocuting light traps. In several different tests various colored lights such as red, green, light blue, dark blue, blue violet, ultra-violet (all discharge tubes), and white incandescent lamps (25–500 watts) were set up along the shore in order to determine whether the gnats were able to perceive color differences. The type of device shown in figure 9 was used for this purpose. All of the various colored lights and an incandescent lamp were set up at approximately the same intensity. All of the combinations used were compared with a constant as a check against the variations in gnat population due to other ecological differences such as temperature changes, wind currents, etc. The results from these various experiments showed clearly that the gnats have no selective color response. Approximately the same number of gnats was collected from each trap over a given period of time when various colored lights and white incandescent light of the same intensity were set up. The response was due obviously to a function of intensity and not to a difference in wave length of the light.

The next step was to determine whether the number of gnats attracted to lights was proportional to the intensity. A battery of lights (40, 100, 150, 300, 500, 1,000, and 1,500-watt incandescent lamps) was set up along the shore. It was found that the number of gnats captured per second increased rapidly in lamps of from 25 to 300 watts and decreased in number when 1,000 watts was reached; this indicates a point of deterrence. There are 360 gnats in 100 milligrams or 1,650,000 gnats in a pound. Over a 15-minute period the 300-watt lamp captured (approximately, by weight) 1,650 gnats per second. The 1,500-watt lamp attracted approximately the same number of gnats as the 200-watt lamp. Up to the point of deterrence the number of gnats attracted to a light is directly proportional to the increase in the intensity of that light. It was concluded that the number of gnats collected by any similar device depends upon the intensity of the light and the rate at which they are removed from the apparatus.

The people in the vicinity of Clear Lake were using small amber or red-tinted lamps in their homes and stores because fewer gnats were

attracted. This deterrence was commonly believed to be due to the color of the lamps; however, it seemed more probable that it was primarily due to the weak intensity of the lamp and not the tint of the light. To test this, two red discharge tubes in a ratio of 3:1 in intensity were set up. The higher-intensity red light collected approximately three times as many gnats as the lower-intensity red light and about equal the number

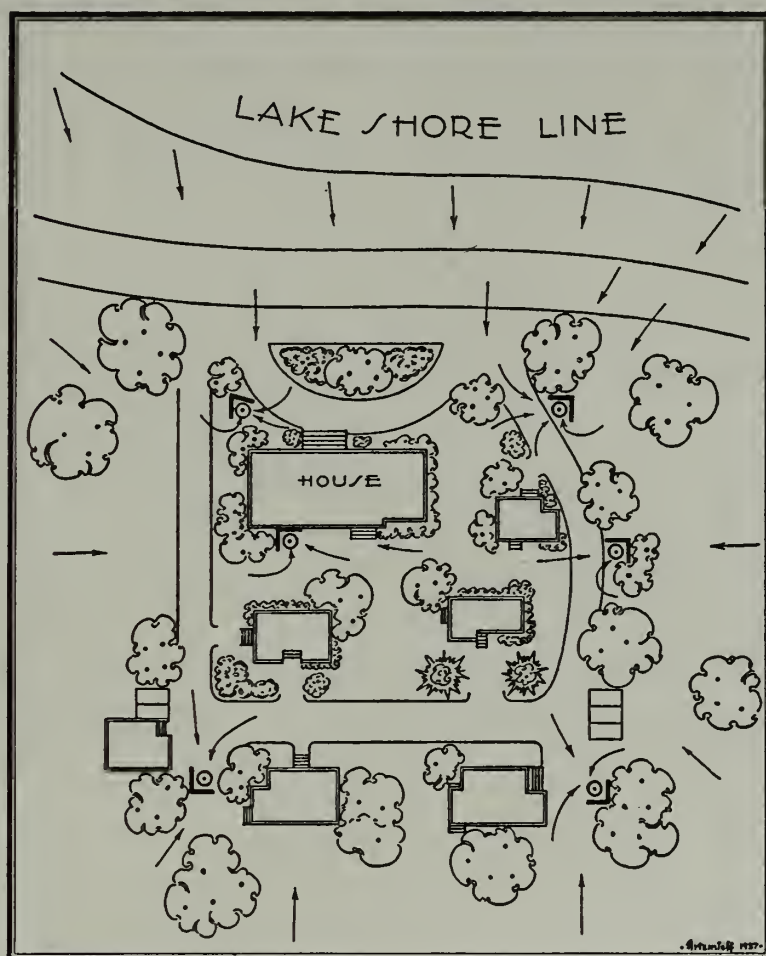


Fig. 10.—Example of arranging light traps at strategic points about the grounds of a summer resort, to attract gnats away from the living quarters. The arrows indicate the direction of flight. Note that the lights are concealed behind baffles in such a way as not to attract the insects into the area.

collected by a 150-watt lamp. Thus irrespective of the red color, an increase in intensity increased the number of gnats.

The insect electrocutors which were first used, like the suction fan traps, became clogged and soon were useless because of the vast number of gnats attracted. This difficulty was largely overcome after considerable experimentation with these devices.

Use of Light-Trap Barriers.—In the light of our present knowledge, the task of completely ridding the Lake of its gnat population would appear to present almost insurmountable difficulties and might even be undesirable. Nevertheless, a large degree of protection against the gnat

pest may be achieved by placing partly concealed insect light traps at strategical points about individual homes or summer resorts; these constitute an effective barrier against general invasion of the gnats. Light traps set openly about the grounds would only result in luring gnats from far and wide; hence the use of substantial baffles arranged at right angles, the light traps being located inside, and always in a position to draw the gnats from the grounds under protection. The lights used for attracting the gnats must be of a higher intensity than those used for ordinary illumination. The arrangement of such a light-trap barrier is diagrammatically shown in figure 10; the arrows in the diagram show the direction of gnat movement.

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